INTEGRATION OF BIM AND RISK MANAGEMENT:A REVIEW OF LITERATURE

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ABSTRACT

This paper is an attempt to explore the available literature pertaining to Building Information Modeling (BIM) and risk management. BIM is a tool which along with Integrated Project Delivery (IPD) can enhance the co-ordination, collaboration and communication of a multidisciplinary complex mega infrastructure project. Building information modelling (BIM) implementation involves various risks, which prevent users from assuring the potential benefits. The objectives of this study are to identify the risks associated with BIM implementation in architectural, engineering and construction projects and model the paths of these risks. Infrastructure projects are subjected to risks throughout all stages of the project starting from feasibility, design, development, implementation and operation. These risks lead to time and cost overrun which drastically reduces the probability of successful completion of the project within stipulated time and cost frame. The project authorities need to adopt mitigation measures to reduce the risk components in the activities of the infrastructure projects.

Key Words : Building Information Modeling(BIM) , Risk , Risk Management

Introduction to BIM

Building information modeling (BIM) has been transforming the architecture, engineering andconstruction (AEC) industry in many countries (Azhar, 2011)[1] and thus received increasingattention from both researchers and practitioners. Application areas of BIM include, but arenot limited to site analysis, design option analysis, 3D presentation, design coordination, costestimating, energy simulation, clash detection, construction system design, schedule simulation, quantity takeoff, site resource management, building performance prediction andoffsite fabrication. Previous studies have identified a number of benefits thatmay be produced by BIM adoption.Number of benefits have been reported in previous studies, such as cost and time saving, reduction in design errors and omissions, reduction in rework and conflicts in construction, better occupantvalue, enhanced construction productivity, better information exchange and better stakeholders' relationships (Azhar2011; Bryde, Broquetas, and Volm 2013)[2]. The different dimensions of BIM are presented below:

BIM 3D = 3 DIMENTION
4D = 3D+SCHEDULING
5D= 4D+COST

6D= 5D+ENERGY

7D= 6D+FACILITY MANAGEMENT

8D= 7D+ACCIDENT PREVENTION (RISK MANAGEMENT)

Risk Management

In a risk management process, risk identification is usually the first step (Low, Liu, and He 2009)[3], and risk categorization, which structures the diverse risks, has been widely accepted as an integralpart of risk identification (Zou, Zhang, and Wang 2007)[4]. In this study, the identification of risks associated with BIM implementation depends on a review of literature using the Scopus database, which has been one of the largest database for multidisciplinary scientific literature (Ameyaw et al. 2016; Le et al. 2014a; Moya-Anegón et al. 2007)[5]. There are mainly 2 types of risk (i) external risk (ii) internal risk. External risks (Fang *et al.*, 2004, El-Sayegh, 2008, Tah and Carr, 2001)[6] mean thoserisks that are outside the project and beyond the control of the project team. The externalrisks include political, economic, social and cultural risks. For example, the political risk mayrefer to the changes or variation of local laws and the economic risk could be the fluctuationof local currency. As external risks are at a macro level such as company or country levelsand are not under the control of the project team, there is a need for a continuous scanningand forecasting through all phases of the project and drawing up company strategies tomanage their effects (Tah and Carr, 2001)[7].Internal risks (Fang *et al.*, 2004, El-Sayegh, 2008, Tah and Carr, 2001)[6]* refer to thosethat are within the project and are more controllable by the project team. The scope ofinternal risks is much broader than external risks and there is a greater opportunity for theproject team to manage them. The number of internal risks in the knowledge-based riskdatabase is much larger than the number of external risks and the relation between differentinternal risks are inter-related and much more complex. Therefore, the internal risks werefurther divided into two groups like local and global, because some internal risks are relatedto the whole project whereas the others may cause effects local to the bridge or individualwork packages (Tah and Carr, 2001)[7]*.First of all, project risk analysis, including the steps of risk identification, riskclassification and defining risk remediationstrategies, should always be followed upby executingthe risk remediation strategies, evaluatingwhether these measures workas expected, and modifythem where required. Often, these risk remediation actions,of a preventive or corrective type, need to be executed by different persons, atdifferent positions, at different moments in time, within the project.Second, the risk management process needs to become a lot more than a tickboxing exercise, in which particularly a lot of paper is produced and processes aremonitored with hindsight. Therefore risk management needs to be transformed from ashould do activity to a want *to* doactivity. This requires full and dedicatedmanagement commitment, as well as true risk management motivation by all personsinvolved in the project, including the external stakeholders.

According to ISO 31010:2009, risk management is a logic and systematic method thatinvolves a set of activities and processes for establishing the context, facilitating riskcommunication, identifying, analysing, evaluating, treating risks, and recording and reportingthe corresponding results properly in a timely manner (ISO, 2009)[9]. Architecture, Engineeringand Construction (AEC) projects start with planning and design, followed by a constructionstage that may last for many months, and eventually will come into the operation stage thatmay last for many decades before demolition. Different risks are present in the differentstages of the project and product lifecycle.

Integration of BIM and Risk Management

Building information modelling (BIM) implementation involves various risks, which prevent users fromassuring the potential benefits. The objectives of this study are to identify the risks associated with BIMimplementation in architectural, engineering and construction projects and model the paths of these risks.To achieve these objectives, 16 risks categorized into 9 groups were identified from a literature review, anda questionnaire survey was conducted with 38 professionals in Australia. The hypothetical risk paths weretested using partial least square-structural equation modelling. Eight risk paths were statistically significant,which further formed nine chains of risk paths. ‘Inadequate relevant knowledge and expertise’ wasthe primary root risk category, and ‘technological issues’, ‘poor information sharing and collaboration’ and‘data ownership issues’ were the secondary root risk category. Additionally, the expense associated withBIM implementation can be offset by the cost savings brought by BIM.

The Current Status of Risk Management

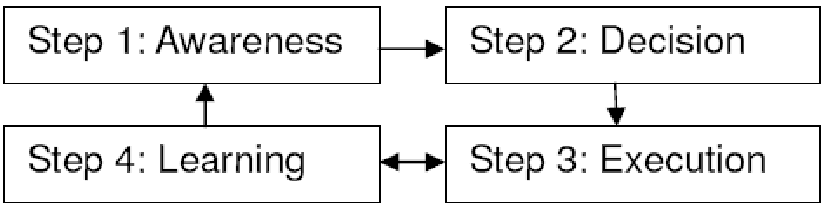
According to ISO 31010:2009, risk management is a logic and systematic method that involves a set of activities and processes for establishing the context, facilitating risk communication, identifying, analysing, evaluating, treating risks, and recording and reporting the corresponding results properly in a timely manner (ISO, 2009)[8]. Architecture, Engineering and Construction (AEC) projects start with planning and design, followed by a construction stage that may last for many months, and eventually will come into the operation stage that may last for many decades before demolition. Different risks are present in the different stages of the project and product lifecycle. This means that regardless of the activity, there is always a possibility that hazards will occur and the whole project may be affected depending on the type of risk and how severe the consequences are. The scope of a risk consists of many issues: damage or failure of structures, injury or loss of life, budget overruns, delays to the construction schedule, etc. Consequently, all project participants need to improve their ability, knowledge and experience to manage risks during the project lifecycle to ensure a safe, successful, and sustainable project.

Challenges in Traditional Risk Management

Existing challenges in traditional risk management can be summarised as (1) Traditional risk management is still a knowledge and experience based manual undertaking, and numerous investigations (Shim et al., 2012, Hartmann et al., 2012, Zhang et al., 2014)[9] have concluded it is time-consuming, error-prone and highly inefficient. In real projects many practitioners still work on two dimensional (2D) platforms and use 2D drawings and paper-based documents to convey the product information. In this process, though some simple techniques, such as checklists, could assist risk identification and analysis (HSE, 2015)[10], it is a significant challenge to combine and link 2D drawings, on-site observations and paper-based documents together for identification and consideration of risks. Decisions are to a large extent made through a “brainstorming” exercise based on existing knowledge and previous experience (2) Risk knowledge management is fragmented and insufficient, and risk knowledge transfer from project to project is difficult. Multi-disciplinary knowledge and experience play a key role in traditional risk management and the corresponding decision making. Project participants, e.g. clients, architects and engineers, gain valuable knowledge and experience from every project and can use them to contribute to future work. In this case, the effective management of this large database of human knowledge and experience as well as flexible and accurate data extraction become a precondition for the success of risk management. However, unlike some manufactured products that can be made automatically, every AEC project has its unique characteristics that are distinguished from others (Clough et al., 2000)[11]. In addition, the process of any AEC project is dynamic and newexperience and new lessons come to light nearly every day. Consequently, another significant challenge is how to effectively manage the "database" of human knowledge and experience as well as extract the correct data flexibly and accurately (3) Communication and collaboration need to be improved in traditional risk management (Zou et al., 2017)[12]. Since projects are completed by a team cooperatively, any common risks will be identified and treated individually, and the corresponding information will be documented and sometimes this work will beignored or forgotten (Kazi, 2005)[13]. This may lead to the risk that information cannotbe presented, shared, recorded, and updated effectively during the developmentprocess of a project. As the project is handed over from designer to contractor, andthen from contractor to the client, people will normally leave the project aftercompleting their tasks. Thus, large amounts of risk information may be lost if it is notrecorded properly and communicated to other project participants.

Risk Breakdown Structure

To learn from and use past project knowledge and experience for managing risks, aneffective way is to work out a comprehensive risk database containing all possible risks thatmay affect the project. The database could facilitate a systematic understanding of all projectrisks, and help the project team link risk information to real projects and make decisionsquickly, e.g. (Kartam and Kartam, 2001, Wang and Chou, 2003)[14]. As construction is bynature a dynamic process with unexpected changes and risks and new information is addedinto the project every day, it is crucial to use a logical and rapid approach for classifying and structuring the large amount of information. Currently a variety of tools have been developed for risk classification, e.g. risk list (PMI, 2004)[15], risk matrix (Markowski and Mannan, 2008)[16], risk maps (Dey, 2010)[17] and RBS (Holzmann and Spiegler, 2011)[18].RBS in concept is a hierarchical structure that allows all types of risk factors and events to be well organised by groups and categories (Holzmann and Spiegler, 2011)[18]*. It is an open, flexible and easily updatable tool and could offer a global view on risk exposure (Mehdizadehet al., 2013)[19].The main advantages of RBS include: (1) to increase overall understanding of risks and facilitate risk communication; (2) to help locate identified risks into relevant places and make special strategies to treat them easily; (3) to provide an architecture for managing risk database and developing risk management software. So far the main approach to develop a RBS is mining risk data from academic publications, project reports, and past project experience and classifying risk factors into a number of logical groups according to the sources of risk (El-Sayegh and Mansour, 2015)[20].



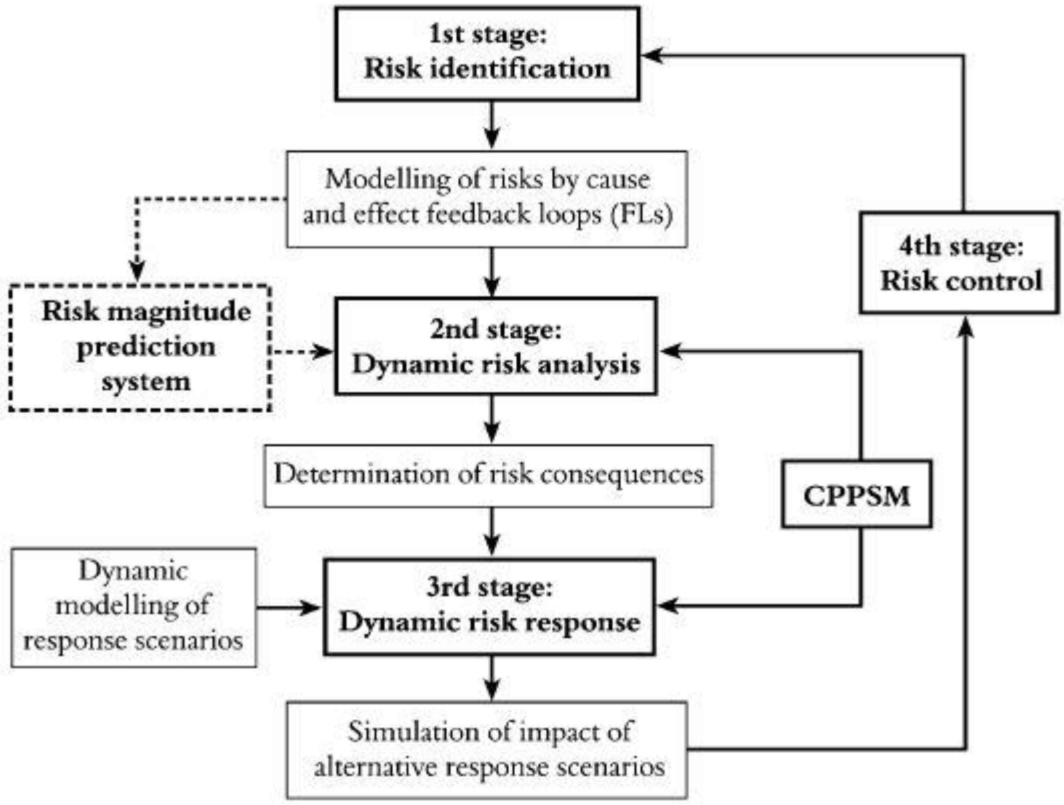


Fig.1 Stages of Risk

Risk Identification

Risk identification is a critical phase in a project risk management process (Low et al., 2009)[21]. A simple but valid method is to develop a risk checklist (Fang et al., 2004)[22]. Through a literature review, a checklist of the risks associated with BIM adoption in the AEC industry was developed. Content analysis has been widely adopted to determine the major facets of data, by counting the frequency that a topic is mentioned or an activity occurs (Fellows and Liu, 2008)[23]. In this study, the risks identified in each literature were marked down andthen similar risks were assembled. The frequency of each risk in the literature was alsocounted. Table I shows that the 16 risks identified from 22 previous studies, with their frequency of appearance in the literature. A total of 16 risks were grouped into nine riskcategories, some of which comprise only one risk.Previous studies on risks associated with BIM adoption overlooked the interactions between risks. For example, Azhar (2011)[1]* and Azhar et al. (2012)[2]* identified several risks associated with BIM adoption, but overlooked the relationships between risks; Ghaffarianhoseini et al. (2017)[24] introduced the risks and challenges of BIM adoption, butdid not explain how the risks interact with each other; and Chien et al. (2014)[25] identified 13 risk factors and but failed to explore the cause-and-effect relationships among risks. Simplyranking risks is not adequate to address these risks because it overlooks the effects of toprisks on others. It is more reasonable to employ a networking of various risk paths,representing the interactions among the risks, than to apply risk checklists only (Eybpoosh et al., 2011)[26]. Thus, this study aims to model the risk paths in BIM adoption using the empirical data from China, which will help locate the root risks and explore the mechanism of interactions among risks.

Some of the common risk sources are(1) Machinery breakdown (2) Inflation (3) Adverse weather conditions (4) Contribution to local community (5) Increased payment in replying with changed labour standard law (6) Discrepancy in geology or topographic conditions (7) Change orders (8) Underestimation of construction costs due to lack of information (9) Inefficiency of owner supervisors (10) Material overuse by subcontractor with poor technique or working habits (11) Changed labour safety laws or regulations (12) Schedule delay caused by rejection of unqualified material (13) Construction accidents resulting from operating errors or carelessness (14) Reworking or delay of work due to poor workmanship of subcontractor (15) Pressure to crash project duration (16) Faulty design not detected by contractor in tendering process (17) Construction errors due to faulty design but not checked in time by contractor (18) Deficit in financial resources and (19) Construction errors due to faulty design but not checked in time by contractor

Risk Data Mining

The next step is to search for valuable risk information from the data collected in risk data collection step by adopting a manual text mining approach. Specifically, a manual analysis through careful reading of each document and interpreting and understanding the text in its relevant context was conducted to identify and record the risk information. As the collected documents use different methods and standards to describe risks, e.g. 'cost increase' and 'budget overrun', it was then important to classify similar risks and put them into different risk groups individually according to the source of risk. Currently there is no consensus on how to develop the RBS (Mehdizadeh et al., 2013)[19], thus a list of key words (e.g. project risk, external risk, global risk, design risk) were identified from previous studies (Tah and Carr, 2001) [7]*, (Choi and Mahadevan, 2008) [27], Mehdizadehet al., 2013)[19]* to be an initial hierarchy for allocating and managing the collated risk information. After this, all identified risk factors and corresponding information were organised into groups and stored in an initial database which is defined as a 'risk pool' in this paper.

Risk Data Analysis

An interpretative approach was used to inform the data analysis and aimed to build understanding of theempirical data. The analysis process resulted in three interconnected components. Firstly, a narrative of the cases were developed to provide an in-depth account of the implementation process, describing key events and their impact on project success, secondly, the empirical data was categorized into the six constructs of the DeLone and McLean IS Success Model to provide a thematic map of the constituent parts of implementation and thirdly, dependencies between each construct were then established to capture the relation between the conditions of implementation and project success.A detailed risk management framework is given in figure 2.

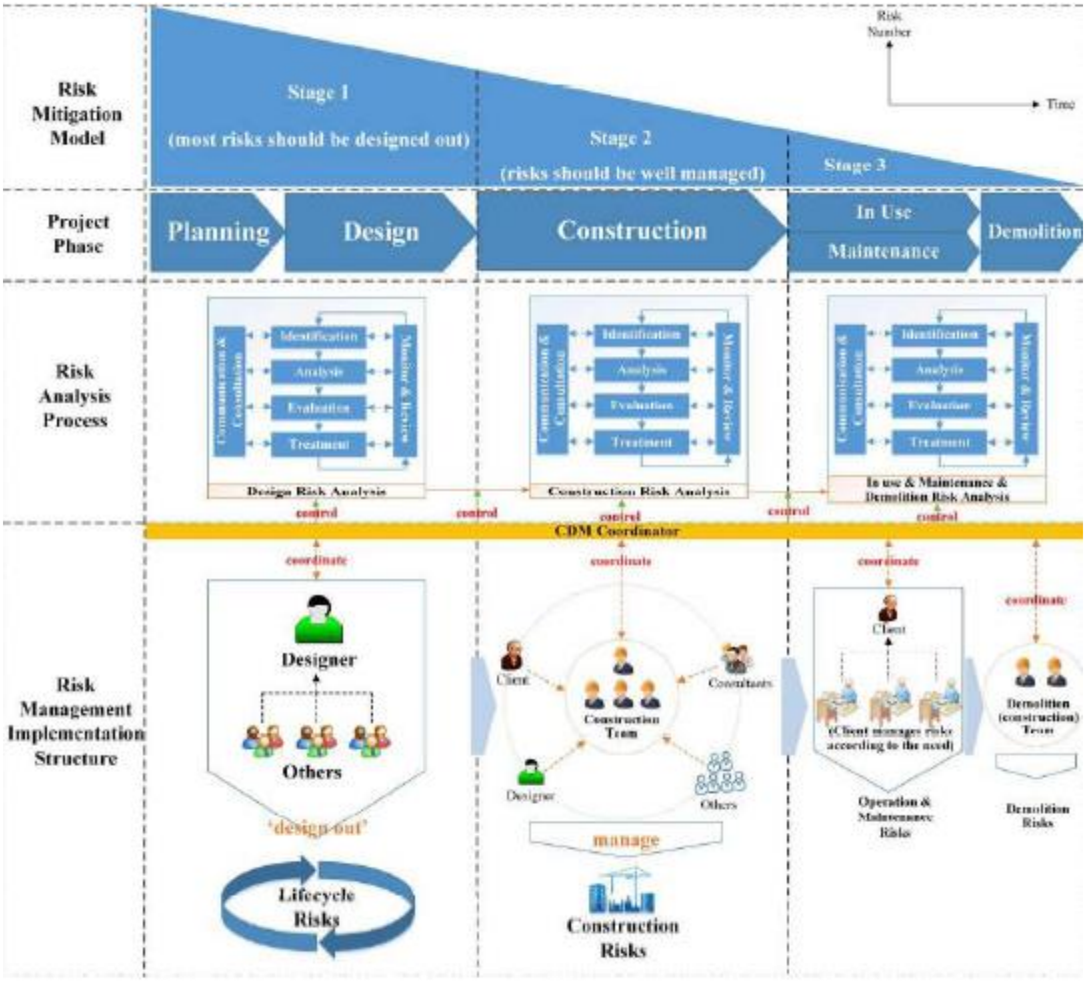


Fig. 2 . A Detailed Risk Management Framework(Zou et al. 2016)[28]

Adopting BIM for Risk Management

In recent years, BIM has seen a rapid increase in use and development in the AEC industry and offers the potential to enhance collaboration and communication, increase productivity and quality, and reduce project cost and delivery time (Azhar, 2011)[1]. In order to overcome the existing obstacles in traditional risk management method, numerous attempts of the use of BIM and BIM-related technologies for risk management have been conducted globally. For instance, BIM itself has been proven as a systematic way to assist early identification and assessment of risks for design and construction through 3D visualisation (Grilo and Jardim-Goncalves, 2010)[29], 4D scheduling (Zhang and Hu, 2011)[30], and 5D cost estimating (Mitchell, 2012)[31]. The spatial visualisation and dynamic modelling of a project in a computer system could effectively facilitate early risk identification and communication (Liu *et al.*, 2014)[32], and assist strategy and decision making to improve safety, time and cost management in construction (Hardin, 2011)[33]. Meanwhile, neutral data formats such as IFC that store standard and customised data for all project elements provide an interoperable digital representation of all project elements enabling interoperability between BIM software and applications (Laakso and Kiviniemi, 2012)[34], which can increase the repeated use of data and reduce the possibility of errors. With the growing development of BIM in the AEC industry, some efforts that could further integrate BIM with risk management have been observed, e.g. automatic rule checking (Eastman et al., 2009, Zhang et al., 2013, Sulankivi et al., 2013)[35], proactive IT (Information Technology)-based safety systems (Forsythe, 2014)[36], and safety training in a virtual gaming environment (Guo et al., 2012)[37]. A critical review by Zou et al. (2016)[28]* summarised the latest developments of using BIM andBIM-related technologies for risk management. Despite these considerable achievements, literature shows that BIM-based risk management has not been widely used in practice because of the following obstacles like (1) Most of the current efforts relate to the design and construction stages and fail to support the development process of a project (Zou et al., 2016)[28]* (2) Because of technical limitations and the lack of "human factor" testing, most of these emerging technologies are still at a conceptual or prototyping stage (Forsythe, 2014)[36] (3) Most of these efforts focus on using or developing new digital technologies to manage particular risks in an ideally assumed scenario, e.g. prediction and prevention of fall accidents (Zhang et al., 2013)[35], and there is still a lack of methodsto use new technologies for risk management systematically. In addition, Zhou et al.(2012)[40] indicated that these considerations to manage safety risk on site are assumption-based actions.Therefore, further investigations are needed to deepen the practical applicability of BIMbasedrisk management.To strengthen the practical applicability of BIM-based risk management, an important solution is to align traditional methods with BIM and take advantages of both for managing risks (Zou et al., 2016)[28]*. A number of studies (Ding et al., 2016)[38] have proved the feasibility and demonstrated the benefitsincluding (1) Through visualising the project and simulating the construction scheduling virtually in a 3D computer environment, BIM could facilitate project team linking existing knowledge and experience with visualisation for identifying risks and makingcorresponding mitigation strategies (2) Knowledge and experience based traditional methods are still playing an important role in practice and could be further strengthened by combining with BIM (3) Risk data could be effectively stored, managed and reused through the project life cycle through merging traditional methods with BIM.It is observed that there are two different development directions of aligning traditional method with BIM for risk management, i.e.(1) product-oriented; and (2) process-oriented. For example, some studies, e.g. (Shim et al., 2012, Zou et al., 2015)[9], demonstrated the feasibility and overall framework of developing a computer tool to visualise and link riskinformation to BIM while other researchers,e.g. (Hartmann et al., 2012)[39], investigated the possibility of integrating BIM into the traditional workflow for risk management or develop a new implementation framework for BIM-based risk management. However, only limited research has been found in this areaand new investigation is still needed.

CONCLUSIONS

Reviewing the available literature it has been observed that researchers have worked on BIM and also on risk management. Adequate literature is available on applications of BIM in building projects. But applications of BIM in infrastructure projects have lesser literature. Adequate literature is available on risk management process like risk identification, risk analysis and risk response planning. Adequate literature is also available on applications of risk management in infrastructure projects. But adequate literature is not available on integrated BIM and risk management model. The present study aims at exploring the possibility of developing an integrated BIM and risk management model for infrastructure projects.

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